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Understanding the link between IS capabilities and cost performance in services: The mediating role of supplier integration

Structured Abstract:

Purpose – The purpose of this study is to explore the link between information systems (IS) capabilities, supplier integration, and cost performance in the service context. Specifically, it empirically investigates how supplier integration meditates the relationship between three dimensions of IS capabilities and cost performance in service firms.

Design/methodology/approach – A survey of 156 UK service firms was conducted and the data analyzed to determine the role of supplier integration in mediating the effects of IS capabilities on firms' cost performance. The research model was tested using structural equation modeling (SEM), and the neural network model was used to rank the relative influence of significant predictors obtained from SEM.

Findings – The results confirmed that supplier integration fully mediates the effects of IT for supply chain activities and flexible IT infrastructure on cost performance, and partially mediates the effect of operations manager's IT knowledge on cost performance. The results showed that operations manager's IT knowledge is the strongest predictor of supplier integration.

Originality – This study takes a step towards quelling concerns about the business value of IS, contributing to the development and validation of the measurement of IS capabilities in the service supply chain context. Additionally, it adds to the emerging body of literature linking supplier integration to operational performance of service firms.

Keywords: Information systems in operations, IS capabilities, supplier integration, cost performance, service supply chains, neural network

Article Type: Research paper

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1. Introduction

The contemporary society is witnessing the phenomenon of evolution of information systems (IS) and technologies that are expected to widely influence almost every aspect of business value chains. Creative use of IS essentially provides new opportunities to businesses to enhance their business performance. However, a recent McKinsey's research shows that only one quarter of firms are doing better in relation to digital revenue grow, while the rest majority encounters the negative effects of digital competition on a company's growth in earnings (Bughin *et al.*, 2018).

Considering large annual investments in information technology (IT), with worldwide spending forecast to reach \$3.9 trillion in 2021 (Gartner, 2021), as well as the expectations that IT brings performance to business, there is a significant concern about whether or not the anticipated business value is being realized from IT/IS investments (Kohli and Grover, 2008). Yet prior studies of the business value of IS have reported mixed results, resulting in the so-called 'IT productive paradox'. Some studies have revealed a direct positive relationship between IT and firm performance (Bharadwaj, 2000; Santhanam and Hartono, 2003; Stoel and Muhanna, 2009; Devece *et al.*, 2017). Others have pointed out contradictory findings, by arguing that IT does not create sustained performance gains (Powell and Dent-Micallef, 1997) or that there is no significant link between IT capability and firm performance, after adopting standardized and homogeneous IS (Chae *et al.*, 2014). As a result, there have been persistent calls for examining the indirect impact of IT on firm performance (Devaraj *et al.*, 2007; Wamba *et al.*, 2017). Such calls led to the investigation of the effect of intermediary factors on the relationship between IT and performance. Most such factors focus on critical organizational processes or capabilities that enhanced by IT (Liang *et al.*, 2010). For example, performance is

likely to be influenced by customer value creation (Ainin *et al.*, 2015) and knowledge management mechanisms which an organization has in place (Perez-Lopez and Alegre, 2012), as they determine how processes are designed and managed (Mithas *et al.*, 2011). Recent research have proposed that process-oriented dynamic capabilities (Wamba *et al.*, 2017) and organizational agility (Felipe *et al.*, 2020) can detect and seize market opportunities with speed, leading them to better performance. The sum of these studies shows inconsistent findings about the possible ways that IT may impact on firm performance and indicates that further research is needed concerning IT and performance (Sundram *et al.*, 2018).

Furthermore, recent research has emphasized that service industries are becoming the next application setting of the 4th Industrial Revolution. This is due to both their size and the fact that service businesses are similar to manufacturing firms in creating and capturing value generated through digital transformation (Mariani and Borghi, 2019). Although research has emphasized that the transformational developments of IS are fundamental to service operations in the digital age (Barrett *et al.*, 2015), there has been relatively little work on examining the mechanisms through which IS affect the operational performance in services (Devaraj *et al.*, 2013; Ostrom *et al.*, 2015).

From the resource-based view (RBV) (Barney, 1991), IS resources by themselves are not sufficiently “unique” and thus it would be more useful and theoretically relevant to focus on the processes they affect (Melville *et al.*, 2004; Chen, 2012). One key organizational process, which has attracted a lot of research attention by supply chain management (SCM) scholars, is the integration with immediate supply chain partners, where prompt sharing and processing of relevant information is needed (Devaraj *et al.*, 2007). The management of the supply chain, particularly through the purchasing function, has been argued to be an enabler of superior performance (Prajogo *et al.*, 2018; Yu *et al.*, 2020). This is because firms increasingly rely on their supplier to obtain competitive advantages (Wang *et al.*, 2016). In services, supplier

management provides a platform for firms to interact with suppliers (Boon-itt *et al.*, 2017). In fact, for some firms (such as sourcing and logistics service providers), supplier management is their core process as their aim is to source goods and services from suppliers (Baltacioglu *et al.*, 2007). Despite this increasing interest, the context of most relevant studies in operations management (OM) and SCM remains in manufacturing settings. Moreover, relatively little distinction has been drawn on the differences between supply chain integration in manufacturing and service supply chains (Yuen and Thai, 2017). Therefore, there is currently a lack of understanding as to whether the results obtained from manufacturing supply chains can be directly extrapolated to service contexts.

Manufacturing and service supply chains are established on the premise that organizations need to manage and control their assets and process uncertainties to best meet customer needs in a cost-effective manner (Ellram *et al.*, 2004; Aitken *et al.*, 2016). However, the management of services is often quite different from manufacturing, because the visible common link of managing the flow of goods is not presenting in service supply chains and flows may not follow observable sequences (Harvey, 2016). The intangibility, heterogeneity, inseparability, and perishability nature of services also makes the service supply chain integration process more dynamic and, potentially, more sophisticated (Boon-itt *et al.*, 2017). Therefore, understanding the relationship between supply chain integration and cost performance of service firms is important (Prajogo *et al.*, 2014).

Despite the emerging evidence of the contributing role of IT/IS capabilities on SCM and operational performance, the empirical studies in this field predominantly operationalized the constructs of IT/IS capability as the use of IT, or as single or formative constructs (refer to Table A1 for a review of this body of literature), which has resulted in a relatively limited understanding of the influence of IS capabilities on operational performance. Many studies have focused on the use of specific types of technologies, for example, integrative information

technologies (Vickery *et al.*, 2003; Vickery *et al.*, 2010; So and Sun, 2011; Kim, 2017), supply chain information technologies (Ward and Zhou, 2006; Devaraj *et al.*, 2007; Li *et al.*, 2009; Tai *et al.*, 2010; Vanpoucke *et al.*, 2017; Yu *et al.*, 2020), or the patterns of IT use (Subramani, 2004; Sanders, 2008; Jiang *et al.*, 2020). While other studies have operationalized IT as highly aggregated concepts (Sanders and Premus, 2005; Sanders, 2007; Paulraj *et al.*, 2008; Fawcett *et al.*, 2011; Prajogo and Olhager, 2012; Davis *et al.*, 2014; Yu, 2015; Peng *et al.*, 2016; Kim, 2017), or have focused on the impact of IT investments (Fawcett *et al.*, 2011; Devaraj *et al.*, 2013). Although a few studies have considered IT as a formative construct consisting of different sub-constructs (Rai *et al.*, 2006; Asamoah *et al.*, 2020), their tests cannot disentangle the individual role of each IT capability in enhancing SCM. Consequently, these studies investigating the relationships between IT/IS capabilities, SCM, and operational performance are yet to empirically test the influence of different dimensions of IT/IS capabilities on SCM.

In this study, the authors aim to advance knowledge in this area by conceptually breaking down IS capabilities into three dimensions (IT for supply chain activities, flexible IT infrastructure, and operations manager's IT knowledge), and investigating the rank of importance of these dimensions on operational performance in services. The authors provide theoretical arguments that underscore the individual role of the three dimensions of IS capabilities. This study therefore aims to address the following questions:

RQ1: How do IS capabilities affect cost performance in services?

RQ2: How does supplier integration in services influence IS capabilities and cost performance?

This study makes the following contributions. First, responding to calls by the RBV literature to explore IS at the business process level, this study contributes to the IS literature by focusing on how IS capabilities impact firm performance, and the role of supplier integration acting as an underlying mechanism with empirical evidence from UK service firms. Second,

despite previous studies having examined the operational impact of supplier integration for manufacturing firms (Zhang *et al.*, 2018), few studies have empirically operationalized this concept in services. This study adds to this literature and thus respond to recent calls for more research on service SCM (Boon-itt *et al.*, 2017; Liu *et al.*, 2019). Third, it develops and validates the measurement scale of IS capabilities in managing service supply chains, which is consistent with the recent call within the SCM literature to explore a comprehensive range of IT in SCM (Ganbold *et al.*, 2020). Finally, unlike most of the IS studies that examine linear relationships using conventional statistical approaches, this study has engaged a two-staged SEM-ANN analysis. This is appropriate because the development of IS capabilities is a complex process which cannot be fully explained using linear models. This study uses a combination of the linear-nonlinear SEM-ANN model to conduct hypotheses testing for linear relationships, and further identify the ranks of the importance of the input neurons according to the neural network sensitivity analysis which captures the non-compensatory and nonlinear relationships (Leong *et al.*, 2020).

2. Literature review and hypotheses development

The resource-based view of the firm (RBV) considers firms as bundles of resources, which are heterogeneously distributed, and which cause differences to persist over time (Wernerfelt, 1984). The RBV offers a convincing framework through which to analyze the strategic value of IS resources. It sets out a cogent link between firm-specific resources and sustained competitive advantages, providing a useful approach to measure the impact of IS resources on firm performance (Wade and Hulland, 2004). Additionally, it provides guidance on how to differentiate various types of IS resources, and how to investigate their separate impacts on firm performance (Santhanam and Hartono, 2003).

This study adopts RBV to explain a firm's superior performance using IS resources

classified as *outside-in*, *inside-out*, and *spanning* (Wade and Hulland, 2004). As this is a general typology, it needs to be situated within appropriate research contexts and with variables tailored to the specificity of the IS domain. Further, the types of IS capabilities also need to take consideration from the perspective of the business and the firm's choices about how and where IS resources were to be deployed (Stoel and Muhanna, 2009). This study focuses on a taxonomy that captures the manner in which IS resource endowments are deployed in support of supply chain processes and is therefore helpful for understanding IS capabilities in the context of SCM. IS capabilities in this study refer to firm-specific IT assets and abilities that influence how post-implementation IT applications and IT-related resources are used in the supply chain environment, namely, (a) IT for supply chain activities (ITSCA), referring to a firm's use of IT for processing transactions, co-ordinating activities, and facilitating collaboration with suppliers and customers through information sharing. The use of IT for supply chain activities represents *outside-in IS capabilities* that facilitate a firm's efforts to manage the linkages with its suppliers and customers; (b) flexible IT infrastructure (ITINF), referring to a firm's ability to deploy a shareable platform that supports a foundation for data management, a communications network, and an application portfolio. A flexible IT infrastructure represents *inside-out IS capabilities* for a firm and these capabilities influence the strategic use of IT; and (c) operations manager's IT knowledge (OMITK), reflecting the overlapping know-how between IT and line managers. OMITK is defined from the perspective of the line manager and refers to the knowledge that the operations manager possesses about how IT can be effectively used to achieve the supply chain processes and operational activities, representing *spanning IS capabilities* for a firm. The following section discusses the hypotheses underlying the research model (Figure 1).

Figure 1 here.

2.1 Impact of IS capabilities on supplier integration

Supplier integration involves strategic information-sharing and collaboration between a focal firm and its suppliers with the aim of managing cross-firm business processes (Lai *et al.*, 2010). In the context of services, capacity may be understood in a manner similar to inventory in manufacturing, in that it allows a supply chain to increase its production level in order to respond to customer demands (Akkermans and Voss, 2013; Boon-itt *et al.*, 2017). Information flows in the service supply chain, including information sharing and feedback, are thus critically important as they allow for the effective management of the uncertainty surrounding customer demand (Field and Meile, 2008). In particular, Ellram *et al.* (2004) identify information flow as especially vital for the co-ordination of all activities between service providers and their supply partners. Similarly, Baltacioglu *et al.* (2007) consider information flow and technology management to be essential for the successful co-ordination of all key functions in the service supply chains.

ITSCA and supplier integration. ITSCA refers to the extent to which a firm has adopted IT for processing transactions, coordinating activities, and facilitating collaboration with suppliers and customers through information sharing. They enable and improve the sharing and exchange of information and data between the focal firm and its suppliers. The adoption of IT for managing supply chain activities supports a firm's ability to communicate with, and transfer data to and from, its suppliers (Bakos and Katsamakas, 2008). For instance, Internet-based technologies have significantly improved collaboration and integration among supply chain partners, permitting more efficient demand forecasting and order scheduling (Peng *et al.*, 2016), as they have enabled accurate and efficient information exchange between buyers and suppliers (Boon-itt *et al.*, 2017).

H1a. The higher the use of ITSCA, the higher the degree of supplier integration.

ITINF and supplier integration. ITINF refers to a firm's ability to deploy a shareable platform that supports a foundation for data management, a communications network, and an application portfolio. The flexibility of a firm's IT infrastructure is manifested by the extent to which the firm adopts standards for the components of that IT infrastructure (Ray *et al.*, 2005). Standards for hardware, operating systems, and communications networks, imply that data and applications can be shared and accessed throughout the organization (Ravichandran, 2018). ITINF provides a platform that enforces standardization and integration of data and processes (Lu and Ramamurthy, 2011). It supports process integration by establishing collaborative connections among separate resources owned by the focal firm and its suppliers. ITINF also increases information transparency and enables real-time, consistent, and comprehensive information sharing between the focal firm and its suppliers (Antons and Breidbach, 2018). Data on products, processes, customers, performance and capabilities is a key asset in an electronically-connected business environment. Firms strive to manage data assets independently of applications, making them available organization-wide to promote initiatives concerned with supplier integration in terms of information sharing and collaborative planning (Sengupta *et al.*, 2006).

H1b. The higher the degree of ITINF, the higher the degree of supplier integration.

OMITK and supplier integration. OMITK refers to the knowledge that the operations manager possesses about how IT can be effectively used to achieve the supply chain processes and operations activities. Previous studies have argued about the importance of the shared knowledge of IT among line managers in determining the value of IT (Ray *et al.*, 2005; Tallon, 2008). OMITK influences the level of alignment between the IS and other functional areas of a firm, enabling effective information sharing and relationship building across the firm's internal business functions (Wunderlich *et al.*, 2013). A firm with a high level of internal

communication and co-ordination will be more capable of achieving a high level of external integration (e.g., Flynn *et al.*, 2010). From the perspective of organizational capability, a firm with a high level of internal communication and coordination is better able to secure a higher level of external integration (Zhao *et al.*, 2011). Zhang *et al.* (2018) find that information sharing between internal departments is related to external co-operation with partners. Therefore, effectiveness between internal business functions facilitates the firm's understanding of its suppliers (Boon-itt *et al.*, 2017).

H1c. The higher the degree of OMITK, the higher the degree of supplier integration.

2.2 Mediating effect of supplier integration on cost performance

Similar to manufacturing, cost can provide a competitive edge in the service sector (Prajogo *et al.*, 2014). With a high level of information sharing and collaborative planning with suppliers, a firm is more likely to receive accurate supply information, which will lead to better service delivery plans and reduced inventory and capacity costs (Lockstroem *et al.*, 2010). Thus, supplier integration enables service providers to exploit economies in service delivery and minimize service costs (Baltacioglu *et al.*, 2007; Kim *et al.*, 2010).

ITSCA, supplier integration and cost performance. The use of ITSCA can promote supplier integration by reducing the transaction costs and uncertainties between a firm and its suppliers (Peng *et al.*, 2016). It can reduce transaction costs, by making coordination more efficient, and by reducing the risk of being exploited in a relationship (Shou *et al.*, 2018). In addition, a firm's use of ITSCA enables the integration of information flow which increases the accuracy of planning and scheduling. IT-enabled sharing of information with the focal firm's suppliers facilitates the firm's ability to cope with uncertainties and changing demand (Sengupta *et al.*, 2006). Using ITSCA can provide accurate and timely exchange of information that mitigates some of the uncertainty in decision-making (Boon-itt *et al.*, 2017), so that the material

movement or service delivery can be coordinated between the focal firm and its suppliers, which in turn results in reduced inventory or capacity costs.

H2a. Supplier integration mediates the relationship between ITSCA and cost performance.

ITINF, supplier integration and cost performance. Through enabling free retrieval and flow of data, communications networks and standardized application portfolio, the adoption of ITINF increases information transparency and enables real-time, consistent, and comprehensive information sharing between the focal firm and its suppliers (Lu and Ramamurthy, 2011). Accurate and real-time information on supply can act as an enabler of cost-effective management on the service provider's capacity and staff availability for service delivery in service supply chains (Akkermans and Voss, 2013). ITINF improves co-ordination efficiency between the focal firm and its suppliers (Ravichandran, 2018). In a service context, excessive or inadequate capacity holding is equally expensive for the service provider (Boonitt *et al.*, 2017). By streamlining information flow, ITINF contributes to increased supply chain efficiency and reduced costs (Zhu and Kraemer, 2005).

H2b. Supplier integration mediates the relationship between ITINF and cost performance.

OMITK, supplier integration and cost performance. Beyond their technological capabilities, firms must possess the ability to understand the business value of IT in the supply chain environment (Tallon *et al.*, 2019). OMITK is an important capability that enables the firm to conceive, implement, and use IT for information sharing and collaboration between different functions within the firm. Such capability reflects the extent to which the firm's management understands the value of IT investments and the processes of alignment between the IS function and other functional areas of the firm (Lu and Ramamurthy, 2011). OMITK provides the service provider with the ability to absorb, through the organization's IT knowledge structures,

information regarding appropriate IT functions and innovations to support operational tasks. Firms that have developed this capability can more readily link with external suppliers (Zhao *et al.*, 2011). OMITK-enabled innovations facilitate service providers' efforts to obtain increased visibility of supply assets and capability (Williams *et al.*, 2013), leading to reduced inventory or capability holding costs. Appropriate capacity planning also ensures that the service provider can enjoy high labor productivity in terms of reduced backlogs (Liu *et al.*, 2019).

H2c. Supplier integration mediates the relationship between OMITK and cost performance.

3. Methodology

3.1 Survey administration and data collection

The data were collected via a web survey sent to 1,158 service firms in the UK, sampled from the Dun and Bradstreet (D&B) database. Respondents were asked to report on their firm's IS capabilities on supplier integration and cost performance. To ensure that respondents had the expertise to accurately respond to the questions, the survey was sent to senior managers with titles such as 'Vice President,' 'Manager,' 'Director' or 'Head', and with the functional area of 'Operations'. Sample analysis showed 98% of the total respondents identified themselves as Operations Managers, Operations Directors, Head of Operations, or Operations Executives, thus indicating that the respondents were knowledgeable upper-management professionals in the operations function of their organizations. Further sample characteristics are provided in Table I.

The questionnaire was pilot tested and validated with MBA class at a leading UK Business School to collect feedback and suggestions for improvement and clarity from the MBA executives. Minor changes were made to the survey instrument. The survey was then administered following the procedures consistent with the web survey implementation of

Dillman *et al.* (2014): (a) *Personalization*: all operations contacts were personally contacted, by including titles, names, specific positions, and firm names. In order to increase personalization, the emails were sent to their individual business email account. (b) *Initial email invitation* included the uniform resource locator of the web questionnaire and instructions on how to access it, along with a description of the research and the importance of response, was emailed to each manager. The detailed and specific instruction about how to access and complete the survey was included to facilitate the efforts of those respondents who may have been unfamiliar with the web survey. All emails were sent from the official university email account of the author, in order to increase credibility. (c) *Multiple contacts*: sending multiple contacts to potential respondents of a web survey is the most effective way to improve response rates. Since it is relatively inexpensive to send additional contacts via email, a researcher can often leave the final decision on the number of follow-ups to send until well into the fielding process. In this study, a four follow-up contact strategy was used following the advice provided by Wygant *et al.* (2005). After two weeks of the initial invitation, three reminder emails were sent to the respondents.

A total of 1,158 questionnaires were originally sent to the respondents. After removing 18 surveys returned due to company policies not to respond, a total of valid 156 responses were received (13.68% response rate). Tan and Wisner (2003) noted the increasing level of survey fatigue among practitioners may lead to low response rates in the fields of OM. The response rate for this study is comparable to or better than other survey-based studies in OM, e.g., 6.3% in Li *et al.* (2005), 13.5% in Huo *et al.* (2014), and is consistent with response rates of UK-based studies in OM, e.g., 10.3% in Carey *et al.* (2011). To ensure a representative sample, the authors tested for non-response bias, and gathered objective data.

Table I here.

3.2 Non-response bias

To ensure that the sample of responses collected was representative of the population, non-response bias was tested through comparing the early wave of returned surveys to the late wave (Armstrong and Overton, 1977). Mann-Whitney U and Kolmogorov-Smirnov Z tests were used to compare early and late responses across all the variables in the survey. No statistically significant differences among variables were found, suggesting that the non-response bias is minimal.

3.3 Common method bias

Since data were collected from a single person at a single point in time, strong efforts have been made to design and test the questionnaire thoroughly to minimize the possibility of common method bias. Both procedural remedies and ex post empirical testing were engaged. First, Harman (1976)'s single-factor test was applied. All measuring items were analyzed together, and no single factor accounted for the majority of the variance (greater than 50%). In addition, the un-rotated factor analysis demonstrated four factors with eigenvalues higher than 1, the result of exploratory factor analysis shows that the first factor accounts for 42.786%, which is not the majority of the total variance. Moreover, using AMOS 21, the authors applied confirmatory factor analysis (CFA) to conduct Harman's single factor test again. The model fit indices of the single factor model (CMIN/DF=6.900 $p < .001$, NNFI=0.575, CFI=0.625, and RMSEA=0.195) were much worse than the suggested values (O'Leary-Kelly and Vokurka, 1998). Despite the fact that this study was based on a single source of informants, the results of the single-factor test indicated that common method bias was not considered an issue for this data set (Podsakoff et al., 2003).

Second, objective data was obtained for comparison purposes. The questionnaire gathered information on the number of employees and the relative perceived cost performance of the

participating organizations. It did so by asking about the relative cost of the service and the labor productivity. This study also drew upon objective data from annual reports and compared these to the survey responses. Although such data were available for only a limited sub-sample, the authors were able to compare employment and cost performance with the objective measures.

Collection of data on the number of employees used a 5-point interval measure. Coding of the employment data from the annual reports utilized the same interval (Lages *et al.*, 2013), revealing correlations between the subjective and objective measures of .678, $p < .01$ (sample size of 66). In addition, while objective data on a comparison of cost performance among firms was unavailable, it was possible to compare perceptual cost performance with actual profit. To rate their cost performance, respondents were asked to indicate how well they perform when compared to their competitors in the industry. Naturally, respondents would compare relative performance with the profit of the competition as it would be difficult for them to know much about their competitors' costs. The EBITDA margin (Earnings Before Interest, Taxes, Depreciation and Amortization) was therefore used as the measure of profit. Coding of EBITDA margins used a 7-point scale with the average industrial EBITDA margin as the 'middle option'. Table II shows that the correlations between the objective percentage EBITDA margins and the corresponding perceptual cost performance items (low cost service, and high labor productivity) are positive and significant (.347 and .371, respectively). Together, the procedural and empirical approaches suggest that common method bias is minimal.

Table II here.

3.4 Measures

The survey scales were either established or developed from the relevant literature. Specifically, ITSCA is represented in the survey by measuring the extent of implementation of 18 different

types of process-level IT applications used in the service industry (Ray *et al.*, 2004; Ray *et al.*, 2005; Rai *et al.*, 2006; Tsikriktsis *et al.*, 2004; Sengupta *et al.*, 2006; Thun, 2010). Consistent with prior IS and OM research (e.g., Banker *et al.*, 2006; Heim and Peng, 2010; Kulp *et al.*, 2004; Saldanha *et al.*, 2013), the extent of implementation (adoption) of each type of IT application is measured on a 2-point scale indicating whether or not it is currently used based on the data provided by operations managers. For each firm, therefore, the values of IT applications (sum of the number of applications) represent the extent of implementation (Hitt *et al.*, 2002).

The measures for ITINF were adapted from those of Ray *et al.* (2005) and Chen *et al.* (2009). The scale assessed the degree to which the firm has established corporate rules and standards for hardware and operating systems to ensure platform compatibility; and has identified and standardized data to be shared across systems and operations departments.

The measures for OMITK were adapted from those of Bassellier *et al.* (2003). The scale asked respondents to indicate the extent to which they agreed that there is a common understanding between IT and operations managers regarding how to use IT to improve operational performance.

The measures for supplier integration were adapted from those of Sengupta *et al.* (2006), Baltacioglu *et al.* (2007), Ellram *et al.* (2004), and Flynn *et al.* (2010). In this study, supplier integration includes information exchange, quick ordering systems, Strategic partnership, Participation level in design stage, the sharing of production/service delivery schedule, inventory/staffing availability, production/service plans between a firm and its suppliers.

The measures for Cost performance were adapted from those of Safizadeh *et al.* (2003), Giannakis (2011) and Prajogo *et al.* (2014). Respondents were asked to rate their cost performance as compared to their competitors' performance in the industry in the areas of low cost service, high labor productivity, and cost effectiveness of process technology.

Control variables. It has been widely noted that larger firms may have more resources and may be in a better position to enjoy performance gains due to their ability to garner economies of scale (Rai *et al.*, 2006). To account for such relationships, firm size was controlled for by including the number of employees. Further, since the salient features of industries (technological change, regulation, IT standards, etc.) can shape how IS are used within focal firm business processes to achieve performance impacts (Melville *et al.*, 2004).

3.5 Reliability and validity analysis

CFA was used to check convergent validity, following the two-step procedure suggested by Anderson and Gerbing (1988). CFA was conducted by correlating the constructs (ITINF, OMITK, SI, and Cost). The measurement model shows a good model fit: comparative fit index (CFI) = 0.972, X^2/df is <5 (1.491), root mean square error of approximation (RMSEA) is <0.08 (0.056). The non-normed fit index (NNFI) of 0.965, the incremental fit index (IFI) of 0.972 and goodness-fit-index (GFI) of 0.885 further confirm that the measurement model is acceptable. Moreover, as shown in Table III, the standardized coefficients, which range from 0.637 to 0.981, and the significant *t*-value ($p < 0.001$) exceed the required cut-off values of 0.5 and 2 respectively (O'Leary-Kelly and Vokurka, 1998). The average variance extracted values (AVE) range from 0.583 to 0.820 higher than the suggested value (0.50) in the literature (Chin, 1998a). The composite reliability and Cronbach's alpha values are all above 0.863. Therefore, we can claim that the reliability of each construct is acceptable.

Discriminant validity was tested by the AVE comparison method (Fornell and Larcker, 1981). If the square root values of AVE for both the constructs that make up the pair are higher than the intercorrelation between any two constructs in the model, then the latent construct explains its assigned item that it shares with other constructs. Table IV shows that the square roots of AVE (bold numbers in diagonal) are greater than the correlations among the constructs

(off-diagonal values). The result provides evidence of good discriminant validity.

Table III here.

Table IV here.

4. Results

4.1 Structural model

Structural equations modelling (SEM) method was used to test the study hypotheses. Figure 2 shows the overall results for the structural model (numbers show above the arrow represent the standardized regression weight). There is a good model fit, with acceptable values - $X^2/df = 1.607$; CFI = 0.993; RMSEA = 0.063; GFI = 0.996; IFI = 0.994; NNFI = 0.929. The predictive power of path models is assessed by examining the explained variance or R^2 values (Chin, 1998b). The R^2 values for supplier integration and cost performance were 0.242 and 0.168 respectively. These values are in line with prior studies explaining the performance impacts of IT in the supply chain (Rai et al., 2006; Xu et al., 2014; Ganbold et al., 2020), suggesting that the interpretation of the path coefficients is meaningful. The path coefficients indicate that ITSCA, ITINF and OMITK have significant effects on supplier integration. H1a, H1b and H1c are supported. The results also show that supplier integration has a significant effect on cost performance. To test the mediating effect of supplier integration, we used a bias-corrected bootstrapping method. Table VI shows the results of mediating test and the confidence interval of the indirect effect of ITSCA, ITINF and OMITK on cost performance excluding zero, the upper and lower bounds of the indirect effect of ITSCA on cost are 0.104 and 0.005 ($p=0.018$), the upper and lower bounds of the indirect effect of ITINF on cost are 0.099 and 0.003 ($p=0.025$), and the upper and lower bounds of the indirect effect of OMITK on cost are 0.157 and 0.008 ($p=0.024$). This means that the indirect paths from these three variables to cost performance through supplier integration are significant and mediations are established (Zhao

et al., 2010). More specifically, no direct effects were found for the paths from ITSCA and ITINF to cost performance, therefore confirming full mediations (H2a and H2b are fully supported); a direct effect was found for the path from OMITK to cost performance ($\beta=0.222$, $p=0.006$), indicating a partial mediation (H2c is partially supported).

Table V here.

Figure 2 here.

4.2 Artificial neural network

This study employs a multi-analytical approach by combining SEM and artificial neural network (ANN). The SEM-ANN approach is a novel analytical method in IS research. This approach has several advantages compared to the conventional linear statistical techniques, such as SEM and Multiple Regression Analysis (MRA), which can only test for linear relationships and may lead to over-simplification of complex decision-making processes (Chong, 2013; Tan et al., 2014; Liébana-Cabanillas et al., 2017). The ANN model is able to learn complex linear and non-linear relations between predictors and output (Chan and Chong, 2012). Also, ANN is more robust and can provide higher prediction accuracy than linear models (Tan et al., 2014) and may out-perform traditional statistical techniques, such as MRA (Chong, 2013). Furthermore, ANN can learn from the deep learning training session. In fact, ANN is a type of machine learning (ML) because it is able to reduce the number of errors using a feed-forward-back-propagation (FFBP) algorithm. On the other hand, due to its “black-box” nature, ANN is not suitable for hypothesis testing and examining causal relationships (Chan and Chong, 2012). Therefore, in this study, similar to Priyadarshinee et al. (2017) and Leong et al. (2020), a two-stage approach is adopted: first, SEM is used to test the overall research model and determine significant hypothesized predictors, which are then, in a second stage, used as inputs to the ANN model used to determine the relative importance of each predictor variable.

In order to avoid over-fitting, a ten-fold cross validation was performed, whereby 90% of the data was used for network training and the remaining 10% was used for testing, i.e. to measure the prediction accuracy of the trained network (Liébana-Cabanillas et al., 2017). A FFBP multi-layer perceptron (MLP) in SPSS 20 with sigmoid activation function for hidden and output layers was utilized. The number of hidden units was generated automatically. As a measure of the predictive accuracy of the model, the Root Mean Square of Error (RMSE) of both training and testing data sets for all ten neural networks, as well as the averages and standard deviations for both data sets are computed and presented in Table VI. The average RMSE of the neural network model are quite small (0.1415 for training data and 0.0136 for testing data), indicating a quite accurate prediction (Tan et al., 2014).

The importance of every independent variable is a measure of how much the value predicted by the network model varies with different values of the independent variable (Chong, 2013). The normalized importance is the ratio of the importance of each predictor to the highest importance value. The results of the sensitivity analysis are presented in Table VII. Based on the presented neural network analysis, OMITK is the most significant predictor of supplier integration, followed by ITINF and ITSCA.

Table VI here.

Table VII here.

5. Discussion and conclusions

This study aims to empirically investigate the relationship between IS capabilities, supplier integration and cost performance in services. A research model was developed and tested using survey data from UK service firms. The results provide a number of important findings that have both theoretical and managerial implications.

5.1 Theoretical implications

First, IS capabilities have positive effects on supplier integration. This finding is important because it shows the values of IS capabilities in a service supply chain context. Although previous studies have demonstrated the importance of IT/IS in SCM (e.g., Yu, 2015; Kim, 2017), to date there have been limited empirical studies assessing how IS capabilities influence supplier integration in services. Specifically, increasing the implementation of ITSCA enables the accurate sharing of information between supply chain partners, which in turn allows for more consistent and effective decision making. This finding supports the argument that IT can create business value through coherent integration of IT and infrastructure capabilities with a firm's capabilities to improve management of its supply chain processes (Peng et al., 2016). Moreover, ITINF allows the sharing of high quality and transparent information which enables an increased awareness of each partner's competences for cost reduction. This finding supports the argument that supply chain integration requires a higher level of ITINF to reap higher performance by enhancing data standardization and systems integration (Liu et al., 2013). Finally, OMITK is the strongest predictor of supplier integration among the three dimensions indicated by the ANN model. OMITK enables operations managers to learn about ways to access remote systems of partners, synchronize various data standards, and secure information networks. These activities that leverage IS capabilities facilitate firms to enhance technical coordination with supply chain partners. This finding supports the argument that supply chain integration requires managerial IT knowledge to best align IT and business objectives to maximize the role of limited IT resources in access to broad information (Liu et al., 2016). In today's highly dynamic and competitive environment, service firms are making greater investments in information technologies (Mariani and Borghi, 2019) and competing on SCM processes (Boon-itt *et al.*, 2017). Therefore, this study reinforces the importance of IS capabilities in enhancing information sharing and building strategic cooperation with suppliers

in service supply chains. Drawing on the RBV, IT scholars argue that firm performance differentials depend on differences in IT capabilities rather than IT investments (Yu *et al.*, 2017).

This is an important point for service firms when they consider investing in IT for SCM.

Second, as an important source of sustained competitive advantages, supplier integration can enhance cost performance in services. This finding provides empirical support to the notion that supplier integration in service contexts also leads to performance improvements. Although such relationships have attracted considerable attention in the traditional manufacturing setting (Zhang *et al.*, 2016; Shou *et al.*, 2018), empirical studies in service contexts remain limited. Both manufacturing and service sectors have similarities, at least in terms of pressures to reduce costs. However, these pressures alone would not be enough to explain the relationship identified here. As service suppliers usually contribute directly to service delivery and customer contact, a failure in the supply side may simultaneously leads to a failure in performance. Therefore, service supplier integration built on coordination, collaboration, and information sharing is unquestionably critical to service operations management. This result also adds to the mixed empirical findings in the literature on the relationship between IT-enabled supplier integration and operational performance. Inconsistent with the findings of Yu (2015) and Prajogo *et al.* (2018) that no relationship was found between supplier integration and operational performance, and the findings of Sanders and Premus (2005) and Sanders (2007) that supplier collaboration can only indirectly impact firm performance. This study finds that supplier integration has a direct positive effect on cost performance in services. From the perspective of RBV, supplier integration effected by IS capabilities can be understood as a set of firm-specific supply management processes that serves as a cost-effective delivery mechanism. This finding is consistent with Yu *et al.* (2020) who argued that supplier integration plays a more prominent role in promoting operational performance. This study takes a step toward answering a call in the literature for recognizing how the conceptual meaning and

magnitude of supply chain integration in manufacturing supply chains can be applied to services. The results show that similarities can be established in the conceptualization of supplier integration. This means that service supply chains have a common understanding towards the measures or components that constitute supplier integration. In addition, similarities can also be established for the effect of supplier integration on cost performance, which reinforces the importance of supplier integration, as a capability that has access to valuable resources from suppliers, could be a source of competitive advantages (Wang et al., 2016).

Third, supplier integration is an important mediator of IS capabilities impacting cost performance of service firms. The results of this study, and its theoretical underpinning, help explain how supplier integration acts as a mechanism through which IS capabilities positively influence cost performance in service contexts. The analysis indicated that ITSCA and ITINF have no direct effect on cost performance. This is perhaps because ITSCA and ITINF can only be leveraged for cost performance after service providers have developed their capability for supplier integration. This result emphasizes the fact that a certain type of IT capability is ineffective to contribute to superior performance unless the firm also has the systems and processes in place to leverage this type of IT capability (Mithas *et al.*, 2011). This finding is consistent with the RBV perspective that IT as a valuable resource may not be able to create sustained firm performance by themselves (Rai et al., 2006), therefore the effect of valuable resource may go through other organizational capabilities (Liang et al., 2010). Supplier integration as a critical organizational capability can enhance firm performance (Wang et al., 2016). Furthermore, this study found that OMITK has a direct effect on cost performance, confirming a partial mediating role of supplier integration. OMITK enables increased awareness of what IS can achieve for a business to improve cost performance. This finding supports the argument that OMITK enables managers to learn more effective ways to leverage

IS capabilities and enhances their ability to leverage integrated IS capability for operational coordination that facilitates cost reduction (Setia and Patel, 2013). In IT-enabled interorganizational service delivery systems, technological resources alone do not predict the business value of IT (Barrett et al., 2015), it is the managerial skills that adapts supply chain processes and the managerial knowledge that corporates IT strategy are even stronger predictors of firm performance and competitive position, particularly in highly competitive markets (Dong et al., 2009). From the RBV perspective, this finding added to the literature that OMITK is a key IT-related differentiator can lead to competitive advantage as it is not subject to low-cost imitation, and the development of this knowledge is often a path dependent and socially complex process.

Another contribution of this study relates to the measurement of IS capabilities. Most previous studies measured IT by inter- and/or intra-organizational technologies, while others measured IT in rather aggregate terms. These measurements and constructs in use to capture the central elements in the relationship cannot disentangle the individual role of each IT capability in enhancing SCM. In addition, when investigating the effect of IT on SCM, the lack of agreement in the literature on the selection of measurements of IT capabilities has produced a significant cross-study variation. For instance, Peng et al. (2016) found IT capability (operationalized as an aggregated construct) to improve supplier integration, which in turn positively affects firm performance. However, Sinkovics et al. (2011) found that IT capability (operationalized as a single “IT integration” construct) did not improve supplier integration. This study takes a multidimensional approach in operationalizing the constructs of IS capabilities, which allows better capture of the nature of IS capabilities and their effects on supplier integration.

5.2 Practical implications

First, IS capabilities promote supplier integration. Supplier integration is not synonymous with IT capability. Rather, IT capability is a separate construct that promotes supplier integration. This is noted as occasionally firms presume that having IT in place automatically assumes external collaboration exists (Sanders, 2007). Supplier integration is a result of human interactions which can be supported, but not replaced by IT (Li et al., 2009). This is an important point for managers when they consider leveraging various types of IS capabilities. Based upon the findings of this study, efforts of IS capabilities that particularly promote collaboration should be given greater consideration.

Second, supplier integration promotes cost performance. This result was expected since information sharing is one of main tenets of SCM. In particular, the relationship found between supplier integration and cost performance in services is based on the exchange of information rather than goods, as is common in traditional manufacturing supply chains (Boon-itt *et al.*, 2017; Wang *et al.*, 2018). These results empirically indicate that the lessons learned about the role of supplier integration in SCM research can be applied to the service sector. Therefore, the findings will help managers in service firms to recognize the operational impact of building the level of integration with their suppliers. Without proper service supply management, an organization is likely paying too much, reducing its leverage, increasing its complexity, and increasing organizational risk (Ellram and Tate, 2015). Moreover, services should not be viewed as a single homogeneous category in this context. For example, there are differences between retailers that hold some physical inventory and consulting firms whose costs are dominated by personnel expenditures. In this sense, managers must use caution when attempting to benchmark integration processes across service sectors. It is important for service firms to consider the impact of sector-specific considerations when building the level of supplier integration.

Third, the findings suggest that as managers consider the benefits of IS capabilities, it is

important for them to be cognizant of supplier integration as a powerful mechanism, through which IS capabilities can improve cost performance. The results suggest service firms that embark on strategies aimed at developing and leveraging their IS capabilities, should at the same time implement processes that encourage supplier integration. Given the intangibility of services and the fact that production and consumption take place simultaneously, any failure in the supply side may simultaneously turn into a failure in service delivery. Therefore, a greater level of supply-related information sharing and collaborative service delivery would lead to improved performance for low-cost services, high productivity and cost effectiveness of process technology. As a result, the increased attention to supplier integration should lead to better cost performance.

Finally, this study contributes to the measurement of IS capabilities. This study takes a multidimensional approach in operationalizing the constructs of IS capabilities, the findings regarding the impact of the different dimensions of IS capabilities add to the growing, yet nascent, body of IS research on the evaluation of IS business value. The results will help managers to clarify the performance implications of each dimension of their IS capabilities and should motivate increased managerial attention toward IS development within the firm. The implication is that managers should not assume that all types of IS capabilities are equally important in influencing supplier integration. The analysis indicated that OMITK is the most important predictor for supplier integration, followed by ITINF and ITSCA. In the complex supply chain environment, the successful implementation of supply chain integration is not so much a technological problem but a management problem, which requires a thorough understanding of the business processes for all parties involved. When operations managers are aware of what the IT department can do, they are more likely to take initiatives that would help integrate with suppliers and subsequently reduce cost of their services. Firms should always bear in mind that OMITK is the most important IT-related differentiator. Operations and IT

managers are also recommended to systematize the sharing of information on IT capabilities and to do so at both strategic and operations management level (Reichstein, 2019). Firms should also concentrate on strengthening ITINF and give appropriate attention to ITSCA, when implementing supplier integration.

5.3 Limitations and future research

While considerable attention has been paid to ensure the validity and reliability of this study, there are limitations. Firstly, the method of data collection in this study was a survey, which is consistent with a number of survey studies of supply chain integration (Sundram *et al.*, 2018; Yu *et al.*, 2020). However, a cross-sectional survey by its nature, limits the depth of understanding of the value of IS capabilities, since the three dimensions of IS capabilities are complex and develop over time. Secondly, cause-effect relations cannot be inferred due to the static nature of the survey. Longitudinal settings would supply valuable information regarding how supplier integration evolves through the relationship lifecycle. Finally, the authors did not account for country- or culture-specific differences in service characteristics since the scope of the survey was limited to UK service firms.

This study has demonstrated the relationships between IS capabilities, supplier integration, and cost performance in service contexts. Much remains to be investigated, however, about such relationships. Future research may consider the mediating mechanisms in a wider context of supply chain integration (i.e., customer integration, internal integration). Further, this study only focused on cost as the measure of operational performance, and future research may consider additional measures in this respect.

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Appendix

Table A1. Summary of empirical studies on the IT-SCM-performance relationship

Related studies	Theoretical perspective used	IT measures	SCM measures	Performance measures	Empirical Results/key findings
Frohlich and Westbrook (2002)	Rational efficiency	Inter-organizational Technologies (Internet, web-based) ^a	Supply integration (SI), Demand integration (DI)	Operation performance (OP)	Tested in 187 manufacturers and 298 services in the UK. The results showed Internet-enabled SI/DI led to the highest OP in manufacturing, but no such finding in service firms.
Vickery <i>et al.</i> (2003)	Transactions costs	Integrated information technologies (IIT) ^a	Supply chain integration (SCI)	Customer service performance (CSP)	Tested in 57 automotive suppliers in North America. The results showed that the relationship of IIT to SCP was indirect, through SCI.
Subramani (2004)	Transaction costs, resource-based views	IT use for exploitation (ITExploit), IT use for exploration (ITExplore) ^c	Business-process specificity (BPS), Domain-knowledge specificity (DKS)	Operational benefits (OB), Strategic benefits (SB), Competitive performance (CP)	Tested in 131 suppliers of one large retailer in Canada. The results showed that BPS mediated the impact of ITExploit on SB. DKS mediated the impacts of ITExploit and ITExplore on OB and SB.
Sanders and Premus (2005)	IT/SCM literature	IT capability ^b	Internal collaboration (IC), External collaboration (EC)	Firm performance (FP)	Tested in 245 US manufacturing firms. The results showed that IT had a significant direct

					impact on IC, EC, and FP. EC influenced IC, which in turn impacted FP.
Ward and Zhou (2006)	Organizational learning, institutional theory, resource-based view	Internal IT integration (WFIT), External IT integration (BFIT) ^a	Lean/JIT practices	Lead time performance (LT)	Tested in 769 US manufacturing firms. The results showed that lean/JIT practices mediated the influence of WFIT/BFIT on LT. WFIT/BFIT had no direct influence on LT.
Rai <i>et al.</i> (2006)	Resource-based view	IT infrastructure integration for SCM ^d	Supply chain process integration (SCPI)	Firm performance (FP)	Tested in 110 US manufacturing and retail firms. The results showed that IT enabled SCPI, which in turn yielded sustained gains in FP.
Devaraj <i>et al.</i> (2007)	Resource-based view, relational view theory, theory of swift and even flow	eBusiness technologies (EB) ^a	Supplier production information integration (SI), customer production information integration (CI)	Operational performance (OP)	Tested in 120 US manufacturing firms. The results showed that EB was not directly associated with OP, however there was a relationship between EB and SI that led to OP.
Sanders (2007)	System dynamics	eBusiness technologies (EB) ^b	Inter-organization collaboration (IC), Intra-organization collaboration (EC)	Organizational performance (OP)	Tested in 245 US manufacturing firms. The results showed that EB impacted OP both directly and indirectly by promoting IC. IC mediated the relationship between EC and OP.
Sanders (2008)	Organizational learning	IT use for exploitation (ITExploit),	Operational coordination (OC),	Operational benefits (OB),	Tested in 241 US OEM firms. The results showed that the relationship of ITExploit to OB

		IT use for exploration (ITExplore) ^c	Strategic coordination (SC)	Strategic benefits (SB)	was indirect, through OC. The relationships of ITExplore to OB and SB were indirect, through SC.
Paulraj <i>et al.</i> (2008)	Relational view	IT ^b	Inter-organizational communication (IOC)	Supplier performance (SP), Buyer performance (BP)	Tested in 221 US manufacturing firms. The results showed that IOC fully mediated the relationship between IT and SP, and partially mediated the relationship between IT and BP.
Li <i>et al.</i> (2009)	IT/SCM literature	IT implementation ^a	Supply chain integration (SCI)	Supply chain performance (SCP)	Tested in 182 manufacturing firms in China. The results showed that the effect of IT on SCP was mediated by SCI.
Wong <i>et al.</i> (2009)	General theory of network governance	IT-enabled transport logistics ^b	Supplier operational adaptation (SOA)	Cost performance (CP)	Tested in 188 manufacturing firms in Hong Kong. The results showed that the relationship of IT to CP was indirect, through SOA.
Tai <i>et al.</i> (2010)	IT/SCM/Strategic management literature	Web-based procurement systems (WP) ^a	Partner relationship (PR)	Buyer organizational performance (BOP), Supplier performance (SP)	Tested in 137 manufacturing firms in Taiwan. The results showed that use of WP impacted SP and BOP both directly and indirectly through PR.
Tan <i>et al.</i> (2010)	Resource-dependent,	EDI in supplier	Supply chain information	Firm performance (FP)	Tested in 625 manufacturing firms in the USA,

	transaction cost economics, resource-based view	management ^a	alignment (INFO), Supply chain relational alignment (REL)		Europe, and New Zealand. The results showed that EDI affected FP only indirectly via its impact on REL.
Fawcett et al. (2011)	Resource-based view	IT investments ^b	Supply chain collaboration (SCC)	Operational performance (OP)	Tested in 702 US manufacturing firms. The results showed that IT impacted OP directly via SCC.
So and Sun (2011)	Innovation diffusion theory	Extranet/EDI for supplier integration, ERP for organization integration ^a	Perceived usefulness (PU)	Perceived benefits (PB)	Tested in 558 manufacturing firms worldwide. The results showed that EDI/ERP positively influenced PU and consequently led to PB.
Prajogo and Olhager (2012)	Relational view	IT ^b	Logistics integration (LI)	Operational performance (OP)	Tested in 232 manufacturing firms in Australia. The results showed that IT was positively associated with LI, which in turn led to OP.
Devaraj <i>et al.</i> (2013)	Theory of swift and even flow	IT investments ^b	Swift patient flow (SPF), Even patient flow (EPF)	Quality of patient care, Revenue	Tested in 567 U.S. hospitals. The results showed that the relationship between IT and hospital revenue partially mediated by SPF/EPF. The relationship between IT and hospital quality to be fully mediated by SPF/EPF.
Davis <i>et al.</i> (2014)	Resource-based view, contingency theory	E-business use (EB) ^b	Supply chain integration (SCI)	Firm performance (FP)	146 US and 67 Singaporean firms. The results showed support for the intermediate role of SCI

					in attaining FP gains from EB.
Xu <i>et al.</i> (2014)	Resource-based view/ extended resource- based view	IT ^b	Supplier integration (SI), Customer integration (CI)	Business performance (BP)	Tested in 176 manufacturing firms in China. The results showed that IT was associated with SI and CI. SI had a significant effect on BP while CI had a marginally significant effect on BP.
Huo <i>et al.</i> (2015)	Socio-technical theory, configuration theory	IT for suppliers (ITS), IT for customers (ITC) ^c	Coordination with suppliers (SC), Coordination with customers (CC)	Supply chain performance (SCP)	Tested in 617 manufacturing firms in China. The results showed that ITS was associated with SC, which in turn led to SCP. ITC was associated with CC, which in turn led to SCP.
Yu (2015)	IT/SCM literature	IT implementation ^b	Customer integration (CI), Internal integration (II), Supplier integration (SI)	Financial performance (FP), Operational performance (OP)	Tested in 214 manufacturing firms in China. The results showed that IT had a positive impact on CI, II, and EI. II mediated the effect of IT on OP and FP. SI mediated the effect of IT on FP.
Peng <i>et al.</i> (2016)	Process-based view of IT	IT capabilities ^b	Business process management capability (BPMC), Supply chain management capability (SCMC)	Firm performance (FP)	Tested in 127 manufacturing firms in China. The results showed that both BPMC and SCMC mediated the effect of IT on FP.
Han <i>et al.</i> (2017)	Extended resource-	Transactional IT	Process integration	Firm performance (FP)	Tested in 162 UK manufacturers. The results

	based view	flexibility (TITF), Operational IT flexibility (OITF), Strategic IT flexibility (SITF) ^c	capability (PIC)		showed that PIC mediated the effects of TITF and OITF on FP. SITF was directly associated with FP.
Kim (2017)	Resource-based view, relational view, extended resource-based view	IT ^a	Supply chain integration (SCI)	Firm performance (FP)	Tested in 161 manufacturing firms in Korea. The results showed that IT impacted FP indirectly via SCI.
Vanpoucke <i>et al.</i> (2017)	Resource-based view	Information exchange IT use ^a	Operational integration (OI)	Operational performance (OP)	Tested in 563 manufacturing firms worldwide. The results showed that OI mediated the relationship between information exchange and OP.
Prajogo <i>et al.</i> (2018)	IT/OM literature	Internal information management (IIM), External information management (EIM) ^c	Internal process management (IPM), External process management (EPM)	Internal operational performance (IOP), External operational performance (EOP), Business performance (BP)	Tested in 202 manufacturing firms in Australia. The results showed that IPM mediated the relationships between IIM/EIM and IOP/EOP. EPM mediated the relationships between IIM/EIM and EOP.

Asamoah <i>et al.</i> (2020)	Resource-based view	Inter-organizational systems (IOS) use ^d	SCM capabilities (SCMC)	Supply chain performance (SCP)	Tested in 193 manufacturing firms in Ghana. The results showed that IOS use impacted SCP directly and indirectly via SCMC.
Ganbold <i>et al.</i> (2020)	Resource-based view, relational view, theory of swift and even flow	Data consistency (DC), Cross-functional application (CFA), Supply chain application (SCA) ^e	Internal integration (II), Customer integration (CI), Supplier integration (SI)	Product-mix Flexibility, Delivery, Quality, Production costs, Inventory level, Customer service	Tested in 108 large manufacturing firms in Japan. The results showed that CFA/SCA had positive impact on SCI, but DC had a negative impact on II. SCI, especially CI, had a positive and significant impact on all operational performance indicators.
Jiang <i>et al.</i> (2020)	IT/environmental management literature	IT use for exploitation (ITExploit), IT use for exploration (ITExplore) ^e	Green strategy alignment (GSA), Green process coordination (GPC)	Environmental performance (ENP), Economic performance (ECP)	Tested in 206 manufacturing firms in China. The results showed that ITExploit/ITExplore impacted ECP indirectly via GSA. ITExploit/ITExplore impacted ENP indirectly via GPC.
Wong <i>et al.</i> (2020)	Resource-based view, information processing theory	Information security technology (IST) ^a	Information sharing (IS)	Supply chain performance (SCP)	Tested in 240 manufacturing firms in Malaysia. The results showed that IST impacted SCP indirectly via IS.
Yu <i>et al.</i> (2020)	Resource-based view, organizational	Supplier IT (SIT), Customer IT (CIT) ^a	Supplier system integration (SSI),	Operational performance (OP),	Tested in 296 cross-border e-commerce firms (in manufacturing sectors) in China. The results

	capability theory		Supplier process integration (SPI), Customer system integration (CSI), Customer process integration (CPI)	Financial performance (FP)	showed that SIT significantly promoted SSI and SPI, which in turn led to OP. CIT significantly promoted CSI, which in turn led to OP. CIT significantly promoted CPI, which in turn led to FP.
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Notes:

^a IT measured by inter-/intra-organizational technologies

^b IT measured in aggregated terms

^c IT considered as patterns of IT use

^d IT considered as formative constructs

^e IT considered as multidimensional measurement

Table A2. Constructs and supporting literature

Constructs	Supporting References
IT for Supply Chain Activities (ITSCA)	
1. Advanced planning and scheduling	Sengupta et al. 2006; Tsikriktsis et al. 2004; Ray et al. 2005; Rai et al. 2006; Thun 2010
2. Production/capacity planning system	
3. Production/capacity scheduling system	
4. Process monitoring system	
5. Supplier account management system	
6. Supply chain management system	
7. Inventory management system	
8. Purchase management system	
9. Web-enabled Invoices and/or payments	
10. Collaborative business forecasting with suppliers	
11. Scanning/imaging technology	
12. Network with agents/brokers	
13. Web-enabled customer interaction	
14. Call tracking/customer relationship management system	
15. Computer Telephony Integration (CTI)	
16. Customer-service expert/knowledge-based system	
17. Web-enabled customer order entry	
18. Collaborative business forecasting with customers	
<i>The values of IT applications (sum of the number of applications) represent the extent of implementation</i>	
Flexible IT Infrastructure (ITINF)	
1. Established corporate rules and standards	Ray et al. 2005; Chen et al. 2009
2. Identified and standardized data	
<i>1-7 Likert scale: from 'Strongly Disagree' to 'Strongly Agree'</i>	
Operations Manager's IT Knowledge (OMITK)	
1. IT understands operations process	Bassellier et al. 2003
2. IT understands operations strategies	
3. Common understanding between IT and Operations managers	
<i>1-7 Likert scale: from 'Strongly Disagree' to 'Strongly Agree'</i>	
Supplier Integration (SI)	
1. Information exchange with our suppliers	Sengupta et al., 2006; Ellram et al., 2004; Baltacioglu et al., 2007; Flynn et al., 2010
2. Quick ordering systems with our suppliers	
3. Strategic partnership with our suppliers	
4. Participation level of our suppliers in the design stage	
5. Suppliers share their production/service delivery schedule with us	
6. Supplier shares inventory/staffing availability (or data) with us	
7. We share production/service plans with our suppliers	
8. We share demand forecasts with our suppliers	
9. We share inventory/staffing levels (or data) with our suppliers	
10. We help our suppliers to improve their process	
<i>1-7 Likert scale: from 'Not at all' to 'Extensive'</i>	
Cost	
1. Provide low cost service	Safizadeh et al., 2003; Giannakis, 2011; Prajogo et al., 2014
2. High labor productivity	
3. Cost effectiveness of process technology	
<i>1-7 Likert scale: from 'Much Worse than Competition' to 'Much Better than Competition'</i>	

Figure 1 Research model

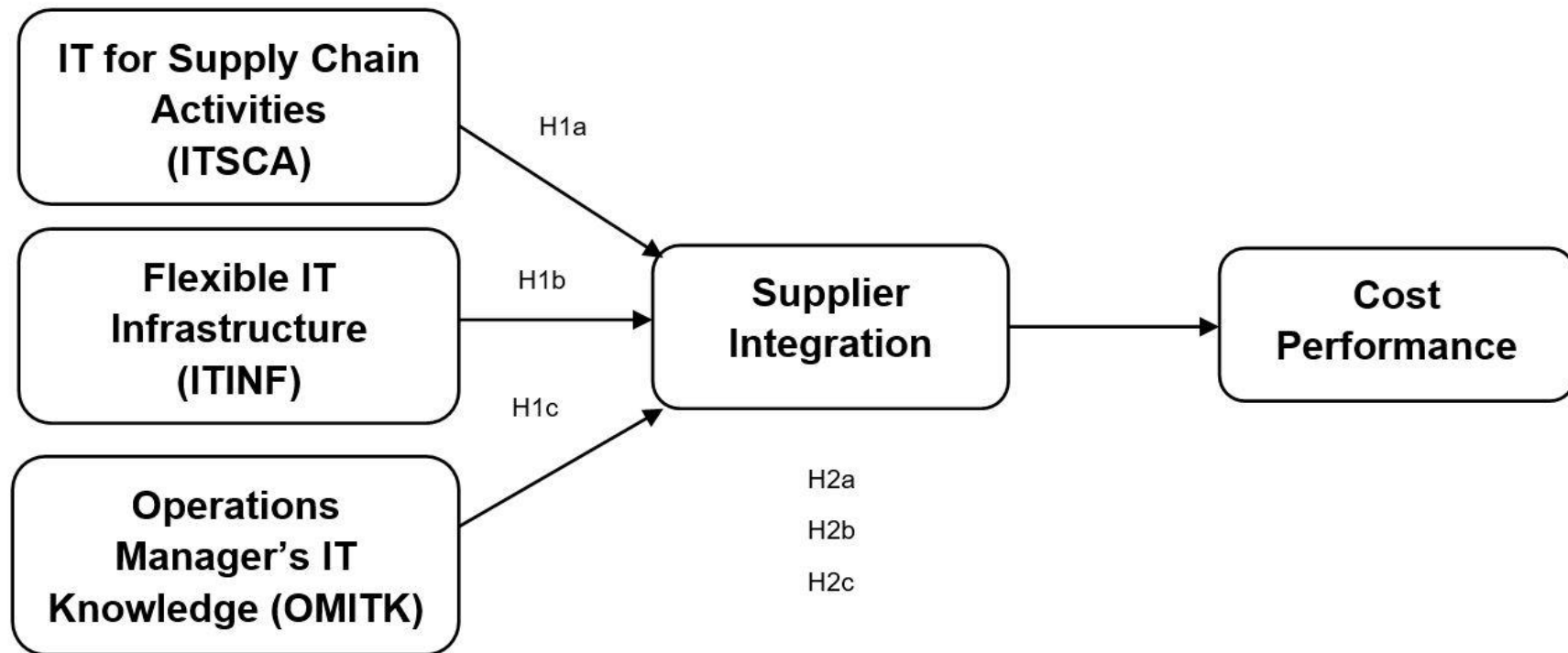
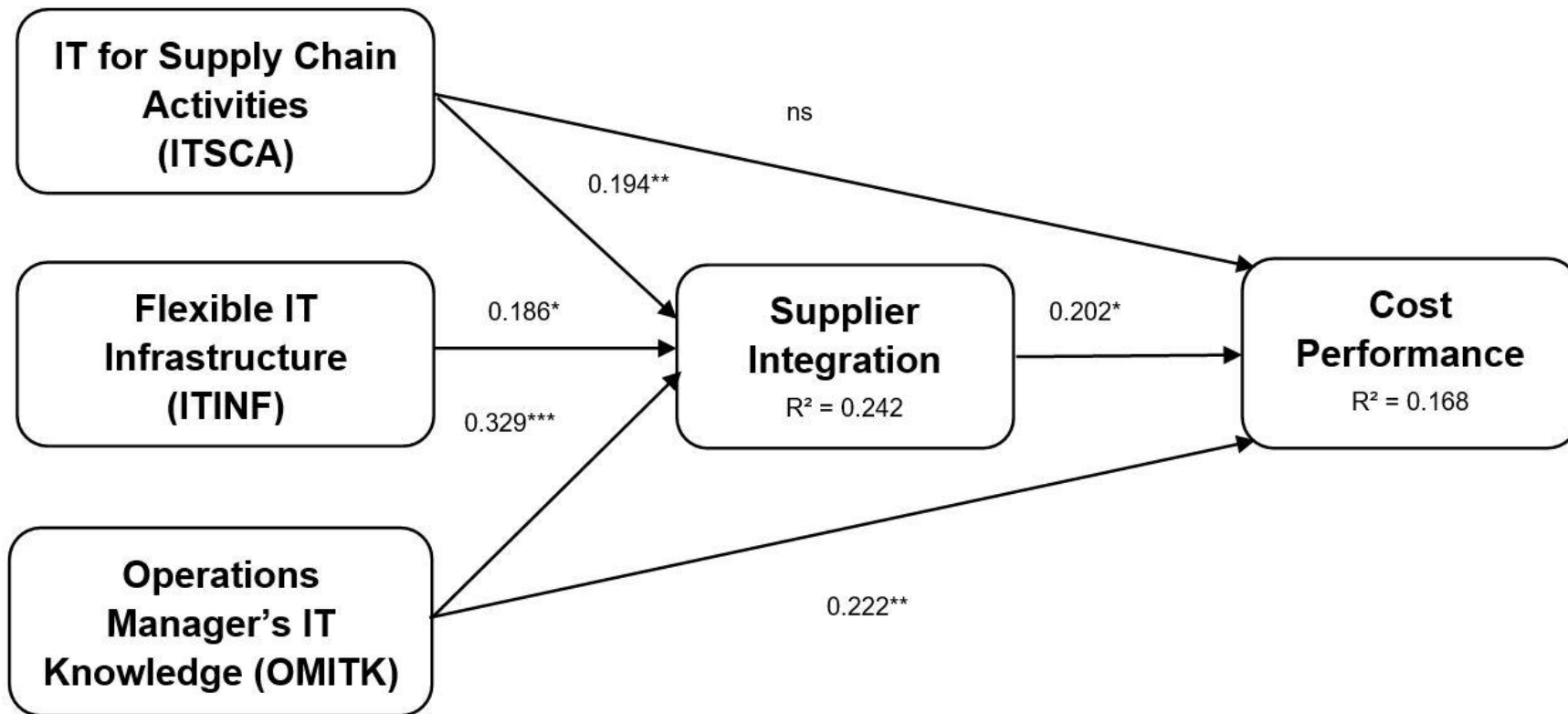


Figure 2 Results of structural model



* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Tables

Table I. Sample characteristics

	Frequency	%
Industry		
1 Education	7	4.5
2 Hotels and restaurants	11	7.1
3 Banks, insurance companies, and other financial institutions	12	7.7
4 Wholesale and retail trade	35	22.4
5 Business activities including real estate and renting	40	25.6
6 Transport, storage and communications	23	14.7
7 Health and social work	14	9.0
8 Other services	14	9.0
<i>Total</i>	<i>156</i>	<i>100.0</i>
Firm Size		
Less than 100	15	9.6
100 – 199	39	25.0
200 – 499	45	28.8
500 – 999	32	20.5
1000 or more	25	16.0
<i>Total</i>	<i>156</i>	<i>100.0</i>
Titles		
Operations Manager	38	24.4
Operations Director	68	43.6
Head of Operations	21	13.5
Executive/VP - Operations	26	16.7
Other	3	1.9
<i>Total</i>	<i>156</i>	<i>100.0</i>

Table II. Post hoc performance matrix

Cost Performance Variable	EBITDA margins
Cost of service	0.347**
Labor productivity	0.371**

* p<.05; ** p<.01; *** p<.001

Table III. Construct loading and reliability index

Construct	Indicator	Item loadings ^a	T-value*	Cronbach's alpha	Composite reliability	AVE
ITINF	ITINF1	0.821	6.107	0.863	0.866	0.765
	ITINF2 ^b	0.925	-			
OMITK	OMITK1	0.885	14.882	0.928	0.932	0.820
	OMITK2	0.981	16.924			
	OMITK3 ^b	0.846	-			
SI	SI1	0.643	8.961	0.946	0.943	0.623
	SI2	0.645	8.996			
	SI3	0.803	15.286			
	SI4	0.837	13.333			
	SI5	0.835	13.261			
	SI6	0.82	12.797			
	SI7	0.858	13.899			
	SI8	0.805	12.422			
	SI9	0.751	11.179			
	SI10 ^b	0.861	-			
Cost	Cost1	0.637	7.509	0.870	0.806	0.583
	Cost2	0.807	8.788			
	Cost3 ^b	0.832	-			

^a Item loading is also known as the standardised regression weight.

^b Fixed parameters

*All item loading significant at 0.01 level.

Table IV. Discriminant validity – AVE comparison

	ITINF	OMITK	SI	Cost
ITINF	0.875			
OMITK	0.314	0.906		
SI	0.355	0.416	0.790	
Cost	0.242	0.393	0.386	0.764

Note: The diagonal elements are the square root of AVE.

Table V. Results of mediating effect test

Standardized indirect effect

		ITSCA→SI→Cost	ITINF→SI→Cost	OMITK→SI→Cost
The confidence interval	Upper	0.104	0.099	0.157
	Lower	0.005	0.003	0.008
<i>p</i> -value		0.018	0.025	0.024

Notes: Level of Confidence for Confidence Intervals: 95; number of Bootstrap Resamples: 5,000

Table VI. RMSE values for training and testing routines

Artificial neural networks	Input neurons: ITSCA, ITINF, OMITK	
	Output neuron: SI	
	Training	Testing
ANN1	0.148101	0.097468
ANN2	0.151334	0.13445
ANN3	0.134649	0.161245
ANN4	0.143809	0.173045
ANN5	0.135033	0.133915
ANN6	0.138274	0.137321
ANN7	0.14578	0.154349
ANN8	0.146239	0.145344
ANN9	0.135119	0.146842
ANN10	0.136314	0.144222
Mean RMSE	0.141465	0.013625
Standard deviation	0.006264	0.02013

Table VII. Neural networks sensitivity analysis

Artificial neural networks	Output neuron: SI		
	Relative importance		
	ITSCA	ITINF	OMITK
ANN1	0.125	0.4	0.475
ANN2	0.125	0.363	0.512
ANN3	0.219	0.358	0.423
ANN4	0.176	0.302	0.522
ANN5	0.277	0.324	0.399
ANN6	0.208	0.38	0.412
ANN7	0.288	0.218	0.43
ANN8	0.238	0.349	0.413

ANN9	0.233	0.313	0.454
ANN10	0.302	0.284	0.414
Average relative importance	0.2191	0.3291	0.4454
Normalized importance (%)	50.55	75.88	100